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SYSTEM ENGINEERING ANALYSIS OF FIREMAIN, FLUSHING, AND WASHDOWN SYSTEM INSTALLED ON LHA-1 AND LPH-2 CLASS SHIPS

July 1982

Prepared for
PLANNING AND ENGINEERING FOR REPAIRS AND ALTERATIONS
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PORTSMOUTH, VIRGINIA
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The analysis documented herein is specifically applicable to the Firemain, Flushing, and Washdown System--ship's work authorization boundary (SWAB) groups 521-1, 521.2, and 523-1--installed on LHA-1 and LPH-2 Class ships. The analysis consider only the systems and equipments installed and the documentation effective as of 22 April 1981. The system was selected for analysis by PERA (ASC) on the basis of its mission criticality and historical maintenance burden.

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by

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SUMMARY

The goal of an engineered operating cycle (EOC) program is to effect an early improvement in the material condition of ships at an acceptable cost, while maintaining or increasing their operational availability during an extended operating cycle. In support of this goal, system engineering analyses (SEAs) are being conducted for various ship classes on selected mission-critical systems and subsystems that have historically exhibited relatively high maintenance burdens. This report documents the SEA for the Firemain, Flushing, and Washdown System installed on LHA-1 and LPH-2 Class ships.

The SEA is an analysis of the impact of historical preventive and corrective maintenance requirements that affect operational performance and maintenance programs of a ship system and the significance of these requirements to an EOC program. The report documents a recommended system maintenance strategy and specific maintenance actions best suited to meeting EOC goals.

This report was developed for PERA (ASC) under Delivery Order FJ07 of Navy Contract N00189-81-D-0126.

The major findings and conclusions of the SEA for LHA-1 and LPH-2 Class Firemain, Flushing, and Washdown System are summarized as follows:

- Most repairs to the equipments of the Firemain, Flushing, and Washdown System can be accomplished by ship's force personnel with occasional IMA assistance.
- Unequal use of the firepumps and their drivers is relevant to the maintenance burden associated with individual firepumps.
- Ship's force and IMAs are capable of accomplishing most major repairs to the firepumps, motors, and steam turbines. Depot-level assistance is normally requested for turbines when a class B overhaul is required because of the depot's special facilities and more experienced personnel.
- Time-directed class B overhaul of the firepumps and drivers during regular shipyard overhaul is not a practical maintenance strategy.

- Either class C repairs or class B overhaul should be performed during ROH on the firepumps, motors, and steam turbines, as determined to be necessary by POT&I results, CSMP, or MCA inspection.
- An "on condition" maintenance strategy is most appropriate for the firepumps and their drivers.
- It would be advantageous to change the periodicity of the annual or cyclic PMS open-and-inspect task to a situational requirement for the firepumps.
- With only minor changes, the PMS requirements for the Firemain, Flushing, and Washdown System are adequate.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

System engineering analyses (SEAs) are being conducted on selected systems and subsystems of designated ships of the Amphibious Force in support of an engineered operating cycle (EOC) program. The SEA is an analysis of the impact of historical preventive and corrective maintenance requirements that affect the operational performance and maintenance programs of a ship system. It serves as a vehicle for assessing the significance of these maintenance requirements to an EOC program. The objective of a SEA is to define and document a maintenance program that will prevent or minimize the need for unscheduled maintenance, while improving material condition and maintaining or increasing system availability throughout an engineered operating cycle.

1.2 SCOPE

The analysis documented herein is specifically applicable to the Firemain, Flushing, and Washdown System -- ship's work authorization boundary (SWAB) groups 521-1, 521-2, and 523-1 -- installed on LHA-1 and LPH-2 Class ships. The analysis considers only the systems and equipments installed and the documentation effective as of 22 April 1981. This system was selected for analysis by PERA (ASC) on the basis of its mission criticality and historical maintenance burden.

The analysis used all available documented data sources from which system maintenance requirements could be identified and studied. These included the maintenance data system (MDS), casualty reports (CASREPs), planned maintenance system (PMS) requirements, ship alteration and repair packages (SARPs), system alteration information, system technical manuals, ship corrosion-control manuals, and Engineered Operating Cycle (EOC) system maintenance analyses (SMAs) previously conducted for functionally similar systems and equipments installed on EOC program ships. Sources of undocumented data used in this analysis included discussions with ships' operating personnel and cognizant Navy technical personnel.

1.3 REPORT FORMAT

The following chapters describe the analysis approach (Chapter Two), present the significant system maintenance experience and essential maintenance requirements (Chapter Three), and summarize the conclusions and recommendations derived from the analysis (Chapter Four). Appendix A defines the system boundaries used in conducting this analysis, and Appendix B lists the specific components that constitute the Firemain and Flushing System as installed on individual ships of the ship classes under study. Appendix C is a summary of CASREP information for the Firemain and Flushing System. Appendix D lists the applicable MIPs reviewed. Appendix E lists approved corrosion control techniques applicable to the system. Appendix F lists all sources of information used in the analysis.

CHAPTER TWO

APPROACH

2.1 OVERVIEW

This chapter describes the approach followed in performing the SEA for the Firemain, Flushing, and Washdown System installed on LHA-1 and LPH-2 Class ships. The systems were selected for analysis by PERA (ASC) on the basis of its mission criticality and historical maintenance burden. Data from sources mentioned in Section 1.2 were used to identify, define, and analyze maintenance requirements that will significantly affect the system's operational availability and material condition. A recommended maintenance strategy and implementation procedures were formulated on the basis of the analysis results. The major steps of the analysis were as follows:

- Task 1: Compile data and prepare maintenance history profile
- Task 2: Analyze problems and causes
- Task 3: Analyze solutions to problems
- Task 4: Document SEA results

The following sections briefly describe each of the major tasks.

2.2 TASK 1: COMPILE DATA AND PREPARE MAINTENANCE HISTORY PROFILE

During Task 1, the configuration, boundaries, and functions of the system were defined; maintenance, engineering, and operating data were collected; and the maintenance history profile was prepared, describing the corrective maintenance historically performed. These items provided basic reference data for the remaining SEA tasks.

2.2.1 Collect Data

The analysis began with the collection of data on the historical maintenance requirements of each system. The resulting data file consisted of four key elements: an MDS data bank, a CASREP narrative summary, a current equipment configuration summary, and a summary of historical maintenance requirements. A library was also assembled from appropriate technical manuals, PMS requirements, SARPs, and copies of previously completed analyses of functionally similar equipments installed on EOC program ships.

The MDS data bank was compiled by examining all MDS data reported from May 1976 through June 1981 for Hulls LHA-1 through LHA-5, and 1 January 1971 through March 1981 for Hulls LPH-2, LPH-3, LPH-7, LPH-9, LPH-10, LPH-11, and LPH-12 (a total of 12 ships).

CASREP information was obtained by reviewing the CASREPs reported on each ship's system during the period of 1 January 1976 through 22 April 1981 for LHA-1 Class ships and 1 January 1978 through 22 April 1981 for LPH-2 Class ships. CASREPs resulting from parts cannibalization of equipments by other ships were not considered.

2.2.2 Define System Configuration

Configuration information was obtained by reviewing available common configuration class lists (CCCLs), the type commander's coordinated shipboard allowance lists (COSALs), shipalt records, and MDS data. Telephone calls to specific ships and cognizant technical personnel, as necessary, confirmed system configuration.

2.2.3 Prepare Maintenance History Profile

The maintenance history profile was prepared from analysis of MDS and CASREP data and review of applicable PMS documentation and SARPs. The maintenance history profile is a working technical package describing the types of corrective and restorative maintenance historically performed on the system, the level of maintenance typically required to perform the work, an estimate of the man-hours required, and the approximate intervals at which these maintenance actions can be anticipated.

2.3 TASK 2: ANALYZE PROBLEMS AND CAUSES

In Task 2 the data summarized on the maintenance history profile forms were analyzed, together with the available engineering data, to identify maintenance, support, and design problems and their associated causes. The problems and their causes were confirmed and data related to additional problems were uncovered through discussion with ships' forces and Navy technical personnel when possible.

2.3.1 Analyze Data to Define Problems

Recurring maintenance requirements affecting the availability and material condition of the equipments constituting the system were identified by screening the maintenance history profiles developed in Task 1. Screening of the maintenance history profiles had two major objectives:

- Identification of recurring failure modes or problems that require IMA, depot, or other off-ship assistance for correction and are common to all engineering designs of the functionally similar equipments installed on the ship classes examined.

- Identification of recurring failure modes or problems that are either unique to or primarily associated with a particular equipment engineering design installed on a limited number of hulls.

Once the problems were identified, the previously completed EOC program SMAs for functionally similar equipments were reviewed to determine whether the same or similar problems had been previously identified on other ship classes. If such was the case, the need for additional detailed analysis was minimized.

2.3.2 Define Causes

Although it is presented as a separate subtask, the definition of problem causes was a continuing process that occurred concurrently with the definition of the problems. Concurrent effort was required for the following reasons:

- Problem causes were sometimes stated in the historical maintenance data.
- Causes or possible causes of problems were identified during discussions with Navy technical personnel or ships' forces.
- Problem causes had previously been identified by analysis of identical or functionally similar systems installed on other ship classes.

In general, the causes were grouped into three categories: maintenance strategy, design, and support.

2.3.3 Summarize Problems and Causes

The problems identified and the causes defined in Task 2 were summarized and carried forward to Task 3 for development of specific solutions. The summary descriptions included the following data:

- A statement of the problem and the most probable cause
- A summary of the pertinent maintenance history and engineering data, including man-hours, number of actions, and level of repair
- Other information affecting the problem, such as redesign work in process, applicable alterations, or the effects of maintenance availabilities

2.4 TASK 3: ANALYZE SOLUTIONS TO PROBLEMS

In Task 3 the problems identified in Task 2 were analyzed so that a recommendation could be made regarding a maintenance strategy, a support strategy, design changes for the associated equipments, or equipment that should be replaced.

2.4.1 Analyze Existing Solutions

The analysis of existing design solutions that might be applicable to the two ship classes under study had two basic objectives. The first was to determine whether the problem was known to the Navy technical community and whether or not a solution had been proposed or defined. To do so, currently authorized shipalts affecting the system or equipment under study were reviewed and, if necessary, interviews were conducted with Navy technical personnel. Where possible, the effectiveness of installed shipalts was assessed.

The second objective was to determine if the specific problem existed in other ship classes and, if it did, whether a solution had been defined and whether it was applicable to the problem associated with the ship classes under study. To meet this objective, previously completed analyses of functionally similar equipments installed on other ship classes were reviewed, and the various problems found were evaluated for similarity. If the problems were determined to be similar to those identified in this analysis, the previously developed solutions were assessed for applicability to the particular equipments installed on the ships under study. If found to be applicable, they were adopted and documented as recommendations in this report without further detailed analysis.

2.4.2 Analyze Potential Maintenance Strategies

Previously developed maintenance strategies for functionally similar equipments installed on other ship classes were reviewed for their applicability to equipment installations on the ships under study. If shown to be applicable by this analysis, they were adopted and recommended for implementation on these classes of ship.

Where previously identified maintenance strategies did not apply to the ship classes under study, maintenance strategies that could possibly apply were analyzed by using reliability-centered maintenance (RCM) logic. This approach used the information developed during previous tasks to answer a series of simple yes-no questions, which led to specific decisions concerning the suitability of scheduling maintenance tasks. Three types of maintenance tasks could result from the decision process:

- On-condition task - Inspect equipment operation to detect either experienced or impending failures
- Scheduled rework task - Rework an item before an established maximum age or operating interval is exceeded
- Scheduled discard task - Discard an item before an established maximum age or operating interval is exceeded

The results of this process led to the development of the maintenance strategies recommended for the systems and equipments under study for which previously developed maintenance strategies were inadequate.

2.4.3 Analyze Potential Solutions to Integrated Logistics Support (ILS) Problems

Analysis of possible improvements to the ILS of the systems and equipments under study was limited to only those systems or equipments having maintenance history profiles that indicated the presence of such problems. Such problems are typically identified during review of MDS or CASREP data. Excessive downtime awaiting parts and the lack of authorized on-board spares as reported in CASREPs indicated the existence of ILS problems. MDS narratives were also used to identify ILS problems, since the deferral codes frequently indicated that a particular maintenance action was deferred for lack of spare parts, technical documentation, or training or experience on the equipment. Where ILS problems were identified, previously completed analyses of functionally similar systems or equipments were reviewed to determine if similar ILS problems had been identified. If they had, and if satisfactory solutions had been defined and recommended, those solutions were adopted and documented as recommendations in this report without further detailed analysis. Otherwise, further analysis was conducted to define an appropriate solution.

Each ILS problem was assessed in terms of its significance and the feasibility of successfully implementing a cost-effective solution. Only those solutions judged to be essential and cost-effective were recommended.

2.4.4 Select Effective Solutions

An effective solution was selected by the analyst on the basis of its merit or essentiality with respect to its projected cost and risk. All candidate solutions, whether resulting from this analysis or from previously conducted analyses of functionally similar equipments, that were judged to improve personnel safety or primary mission reliability were assessed on the basis of projected cost and feasibility. If these candidate solutions were not clearly feasible, or if their value, in terms of reduced maintenance burden or improved equipment reliability, was not significant, they were not recommended for implementation.

2.5 TASK 4: DOCUMENT SEA RESULTS

The Task 4 approach was to present the analysis results in a concise, logical format that included an introduction to the SEA objectives, a summary of the technical approach used, a presentation of the analysis results, and a section listing the specific conclusions and recommendations resulting from the analysis. Appendixes were included as necessary to show pertinent data affecting the system, including a table defining the configurations by allowance parts list (APL) number for each LHA-1 and LPH-2 Class hull included in the analysis.

CHAPTER THREE

RESULTS

3.1 SYSTEM BOUNDARIES AND DESCRIPTION

The Firemain, Flushing, and Washdown System discussed in this report, hereinafter referred to simply as the firemain system (FMS), is composed of various equipments included within SWAB groups 521-1, 521-21, and 523-1. All of the major equipments (listed in Appendix A) were examined to identify maintenance requirements. The major components examined and discussed in this report include firepumps and firepump drivers (electric motors and the steam turbines). The components are listed by APL in Appendix B. Firemain system valves are also discussed in this report in terms of their aggregate contribution to the FMS maintenance burden. The valve maintenance burden is significant only in terms of the combined burden for all FMS valves; therefore, individual valve configurations by APL number are not included in Appendix B.

The FMS proper includes piping and valves from the inboard flange of sea valves to firepump suction flanges; the firepumps, firepump drivers, and associated components; and all piping and valves from the firepump discharge flange to the root valves in the service branches. The washdown part of the system includes piping, valves, fittings, and associated components from the firemain root cutout valves to the spray nozzles. This analysis focuses on the firepumps, their drivers, and the system valves -- the only equipments which represented any significant maintenance burden and for which maintenance requirements were identified.

The primary purpose of the FMS is to provide sea water throughout the ship for safety and fire protection. The FMS also plays a major part in supplying other auxiliary systems throughout the ship with sea water, primarily for use in equipment cooling. The washdown system is arranged to distribute sea water to weather surfaces in sufficient quantities to produce runoff and removal of contaminated materials. The loss of the FMS affects mobility, a primary mission area of Amphibious Class ships.

Each ship of the LHA-1 Class has four 2,000-gallons-per-minute (GPM) steam-turbine-driven firepumps and four 2,000-GPM electric-motor-driven firepumps. All eight firepumps are single-stage, horizontally mounted, centrifugal, split-casing volute units equipped with double-suction impellers and external, grease-lubricated ball bearings. The pump is connected to its driver by a flexible coupling.

Each ship of the LPH-2 Class has two 1,000-GPM steam-turbine-driven firepumps and six 1,000-GPM electric-motor-driven firepumps. All eight firepumps are single-stage, horizontally mounted, centrifugal, split-casing volute units equipped with double-suction impellers and external, grease-lubricated ball bearings. The pump is connected to its driver by a flexible coupling. Table 3-1 provides the identification number, driver, and location of the firepumps for each class.

Table 3-1. SUMMARY OF FIREPUMP IDENTIFICATION AND LOCATION

Ship Class	Pump Number	Driver	Location
LHA-1	1	Motor	Forward Pump Room
	2	Motor	Forward Pump Room
	3	Turbine	Forward Machinery Room
	4	Turbine	Forward Machinery Room
	5	Turbine	After Machinery Room
	6	Turbine	After Machinery Room
	7	Motor	After Pump Room
	8	Motor	After Pump Room
LPH-2	1	Motor	Pump Room 1
	2	Motor	Pump Room 1
	3	Turbine	Fire Room
	4	Turbine	Fire Room
	5	Motor	Engine Room
	6	Motor	Engine Room
	7	Motor	Pump Room 2
	8	Motor	Pump Room 2

Review of the MDS data and discussions with ship's force personnel established that the firepumps experienced unequal use, for several reasons. The first reason is that the firepumps are not all needed at one time. While a ship is in port, one or two firepumps are usually on line; when the ship is under way, two or three firepumps are usually on line. The combination of motor-driven firepumps and turbine-driven firepumps being used varies depending on whether or not steam is available. The second reason is that easily accessible firepumps -- i.e., those located in main machinery spaces versus those in pump rooms -- are used more frequently than inaccessible ones.

3.2 MAINTENANCE REQUIREMENT IDENTIFICATION

The FMS maintenance burden data for selected equipments is presented by equipment APL number in Table 3-2. The calculated burden ranges per equipment per operating year were: firepumps, 0 to 112 man-hours; AC motors, 0 to 80 man-hours; and steam turbines, 8 to 89 man-hours.

Table 3-2. SUMMARY OF MDS DATA FOR THE FIREMAIN SYSTEM

APL	Nomenclature	Applicable Ships	Equipments per Ship	Total Equipment Population	Total Ship Operating Time (SOY)	Ships Reported	JCNs	Man-Hours			Parts Cost (Dollars)	Average Man-Hours per Equipment per Operating Year*
								Ship's Force	IMA	Total		
Firepumps												
016020537	Centrifugal Pump, 1,000 GPM	2	2	4	15.24	2	35	270	167	437	12,143	14.3
016020842	Centrifugal Pump, 1,000 GPM	1	8	8	7.10	1	75	1,092	2,795	3,887	28,509	68.4
016020956	Centrifugal Pump, 1,000 GPM	1	6	6	7.82	1	89	1,294	5,716	7,010	66,045	112.1
016021444	Centrifugal Pump, 1,000 GPM	1	2	2	8.41	0	0	0	0	0	0	0
016032346B	Centrifugal Pump, 2,000 GPM	5	8	40	9.69	4	44	428	493	921	17,773	11.9
016110105	Centrifugal Pump, 1,000 GPM	1	6	6	8.11	1	85	1,211	338	1,549	24,376	31.8
016110259	Centrifugal Pump, 1,000 GPM	1	4	4	7.28	1	79	1,038	531	1,569	29,685	53.9
016110474	Centrifugal Pump, 1,000 GPM	1	8	8	7.28	1	115	1,273	1,008	2,261	21,028	39.2
016110502	Centrifugal Pump, 1,000 GPM	1	4	4	7.28	1	11	88	400	488	3,878	16.8
016110600	Centrifugal Pump, 1,000 GPM	1	6	6	7.13	1	74	864	1,383	2,247	21,000	52.5
016150937	Centrifugal Pump, 1,000 GPM	1	6	6	8.41	1	39	763	122	886	4,372	17.5
	Subtotal	12	-	96	62.82	11	646	8,321	12,953	21,274	228,809	42.3
AC Motors												
174031358B	AC Motor, 300 HP	5	2	10	9.69	1	1	4	0	4	868	.21
174031359B	AC Motor, 300 HP	5	2	10	9.69	0	0	0	0	0	0	0
174180119	AC Motor, 125 HP	1	6	6	7.28	1	10	200	196	396	152	9.1
174750687	AC Motor, 125 HP	2	4,6	10	15.24	2	72	1,524	4,556	6,080	13,379	79.8
174751787	AC Motor, 125 HP	3	1,5,6	12	23.21	2	109	2,245	2,523	4,768	14,795	51.4

(continued)

Table 3-2. (continued)

APL	Nomenclature	Applicable Ships	Equipments per Ship	Total Equipment Population	Total Ship Operating Time (SOT)	Ships Reported	JCNs	Man-Hours: Ship's Force	Man-Hours: IMA	Man-Hours: Total	Parts Cost (Dollars)	Average Man-Hours per Equipment per Operating Year*
AC Motors (continued)												
174754111	AC Motor, 125 HP	1	1	1	7.82	0	0	0	0	0	0	0
174802584	AC Motor, 125 HP	1	6	6	8.41	1	12	314	780	1,094	494	21.7
174752576	AC Motor, 125 HP	1	1	1	8.11	1	2	187	36	223	49	27.5
175503576	AC Motor, 125 HP	1	6	6	7.10	1	30	451	2,040	2,491	3,861	58.5
	Subtotal	12	-	62	62.82	8	236	4,925	10,131	15,056	33,598	46.4
Steam Turbines												
057950071	Steam Turbine	4	2	8	30.93	3	59	1,174	982	2,156	18,936	34.9
057950104	Steam Turbine	1	2	2	7.10	1	20	318	940	1,258	9,425	88.6
057950139	Steam Turbine	1	2	2	7.82	1	18	121	94	215	5,876	13.7
057950140	Steam Turbine	1	2	2	7.28	1	36	596	487	1,083	6,371	74.4
057950185B	Steam Turbine	5	4	20	9.69	5	31	172	125	297	855	7.66
	Subtotal	12	-	34	62.82	11	164	2,381	2,628	5,009	41,463	28.1
Valves and Piping												
	Valves and Piping, LHA-1	5	**	**	9.69	5	201	818	1,007	1,825	43,655	**
	Valves and Piping, LPH-2	7	**	**	53.13	7	1,049	8,013	6,452	14,465	147,459	**
	Subtotal	12	**	**	62.32	12	1,250	8,831	7,459	16,290	191,114	**
	Total	12	-	-	62.82	-	2,296	24,458	33,171	57,625	494,984	—

*Average man-hours per equipment per operating year = $\frac{\text{Total Man-Hours per APL}}{\text{Number of Equipments per APL}} \div \frac{\text{Ship Operating Years}}{\text{Number of Applicable Ships}}$

**Could not be determined because valve configurations were incomplete.

The large differences in the average maintenance man-hours per equipment per operating year among the various component types tend to indicate that the maintenance needs of functionally similar components may be significantly different. However, further examination of the MDS narratives at the individual equipment level revealed that the maintenance experiences for functionally similar equipments were in fact similar. The large apparent differences observed in the maintenance burden data are explained by the following:

- Significantly fewer maintenance actions were reported against the LHA-1 Class ships than against the LPH-2 Class ships. Because the LHA-1 is a new ship class, much of the maintenance may have been accomplished under warranty and therefore not reported.
- Some unusual one-of-a-kind repairs with large man-hour expenditures were reported.
- The firepumps received disproportionate use. (Some pumps are used continually, and some pumps are almost never run. The situation varies from ship to ship.)

For simplicity of presentation, the analysis results and maintenance requirements are discussed by component type. Within each component subsection, the discussion is limited to failure modes and significant maintenance actions that (1) are repetitive, (2) immediately or eventually affect the equipment availability if left uncorrected, and (3) sometimes require outside assistance to complete. Unspecified maintenance actions, repairs judged to be "one time" repairs, and routine repairs -- always completed by ship's force personnel in a relatively short period without outside assistance -- were not evaluated in detail and are not discussed.

The available maintenance data for each component type were examined further for the following purposes:

- To identify the failure modes and significant maintenance requirements associated with the reported maintenance man-hours
- To determine the cause of each failure mode
- To determine an appropriate maintenance level for the correction of each failure mode
- To identify the effect of each failure mode on equipment availability and its associated effect on mission-critical areas
- To develop alternatives that would increase equipment availability and reduce corrective maintenance when warranted

The following sections present the analyses performed for the firepumps, firepump motors, steam turbines, and selected valves of the firemain system, together with resulting recommendations. The data are discussed by functional component in general, and any differences in maintenance experiences among ships, ship classes, or equipment manufacturers are addressed separately.

The significant component failure modes and maintenance requirements are presented in a series of tables. All one-time failures and those failures whose causes could not be identified from the available data are excluded from the data tables. The tables include MDS maintenance actions that have not been reported as completed. Therefore, the actual number of outside-assistance maintenance actions and the total man-hour figures are probably greater than the totals indicated in the tables. However, the tables identify the types of failures and maintenance events that most often require outside assistance to correct and the types that infrequently require outside assistance.

The major components of the FMS and their failure modes are discussed in the following subsections.

3.2.1 Firepumps

Table 3-2 showed that the maintenance man-hour burden associated with the firepumps accounted for 21,274 man-hours, or approximately 37 percent of the total (ship's force and IMA) man-hour burden reported against the selected firemain system components. Further analysis of the firepump MDS and CASREP data identified four significant, recurring types of failures and associated corrective maintenance events for evaluation: bearing replacement; mechanical seal, packing, and shaft sleeve replacement; internal pump repairs; and complete pump overhaul. Table 3-3 summarizes those maintenance actions (referred to as job control numbers [JCNs]), the numbers of JCNs reporting IMA assistance to ship's force, and the total man-hours reported for the significant failure modes and associated maintenance actions for the firepumps.

3.2.1.1 Mechanical Seal, Packing, and Shaft Sleeve Replacement

Maintenance actions on mechanical seals, packing, and shaft sleeves accounted for 40 of the 171 significant maintenance actions reported against the firepumps. The repair or replacement of mechanical seals, packing, and shaft sleeves was a repetitive maintenance action and is expected to continue during future operating cycles.

Approximately 12 percent of the JCNs for the mechanical seals, packing, and shaft sleeves reported IMA assistance. There were 668 reported ship's force man-hours, an average of 17 hours per JCN. There were 513 reported IMA man-hours for the 5 JCNs requiring IMA assistance, an average of 103 IMA man-hours per JCN. Ship's force is normally capable of replacing mechanical seals, packing, and shaft sleeves. However, IMAs are sometimes requested to remachine the worn shaft sleeves.

Five CASREPs were reported for failed mechanical seals and packing of firepumps during the CASREP data period, accounting for 3,457 downtime hours due to maintenance, an average of 691 hours (29 days) per mechanical seal CASREP. The downtime is not representative of the time required to make repairs but rather the total elapsed time between failure and repair completion, which includes "dead time" between discovery of the problem and initiation of repairs. Only one CASREP reported downtime hours due to

Table 3-3. SUMMARY OF SIGNIFICANT FIREPUMP MAINTENANCE ACTIONS

Maintenance Action or Failure Mode	Total JCNs	JCNs Reporting IMA Assistance	Man-Hours		
			Ship's Force	IMA	Total
Bearing Replacement	16	1	363	72	435
Complete Pump Overhaul (Class B)	18	2	630	39	669
Mechanical Seal, Packing, and Shaft Sleeve Replacement	40	5	668	513	1,181
Internal Repairs: • Wearing Rings • Rotor Assembly • Shaft • Impeller • Casing	97	17	3,214	4,324	7,538
Totals	171	25	4,875	4,948	9,823

supply, and the required repair parts were not listed. All of the CASREPs listed a C-2 severity, indicating minor degradation in system capability.

PMS requires that the packing and mechanical seals be inspected monthly for leakage. Depending on the respective MIPs, renewal of mechanical seals is specified as an annual or situational requirement. The apparant randomness of failure indicates that renewal as an on-condition or situational requirement is appropriate. Otherwise, the PMS appears to be adequate, and scheduled outside assistance is unwarranted.

Discussions with ship personnel revealed that good mechanical seals are very hard to obtain through the Navy supply system and that they are therefore being acquired directly from a private source. In addition, the maintenance time consumed in replacing mechanical seals is significantly higher than that consumed in replacing packing. Personnel on one LPH reported that they were planning to replace the mechanical seals with packing on their salt water pumps because of the difficulty and cost associated with mechanical seal replacement. NAVSSES (Code 023) is currently investigating this problem.

3.2.1.2 Internal Repairs and Bearing Replacements

Significant internal repairs included those involving wearing rings, rotor assembly, shaft, impeller, bearings, and casing of the firepumps. Table 3-3 presents the number of JCNs considered to be internal repairs and the number of JCNs that were exclusively bearing replacements. The table lists bearing maintenance actions as a separate category, but for purposes of continuity the bearings are also discussed under internal repairs. When the pump is opened for internal repairs, the bearings are normally replaced, thus accounting for a portion of the man-hours.

A total of 97 JCNs were classified as significant internal repairs, representing 57 percent of the significant maintenance actions reported for the firepumps. IMA assistance was reported for 18 percent of the significant internal repairs, a total of 4,324 IMA man-hours, or an average of 254 IMA man-hours for each JCN reporting IMA assistance. Ship's force man-hours accounted for 3,214 hours, an average of 33 hours per internal repair. Depot-level assistance was rarely reported for internal repairs. Ship's force, with minimal IMA assistance, is capable of performing all the internal repair actions with the exception of repairs to pump casings.

Review of MDS narratives and CASREPs revealed that the most commonly reported failure mode was deterioration of internal parts from normal use. Specific problem areas reported were:

- Deterioration of pump casing in the area of casing wearing rings
- Eroded and corroded impellers
- Excessive wearing ring clearances
- Worn bearings
- Scored and bent shafts

Pump casing deterioration in the area of the casing wearing rings and impeller deterioration are normally caused by a combination of galvanic corrosion and erosion. Pump-to-driver misalignment caused bearing wear, with resultant acceleration in wearing ring clearances and possible shaft damage. Regardless of the failures, the corrective action requires dismantling the pump end and replacing the failed or deteriorated parts.

As stated earlier, ship's force personnel are normally capable of performing most significant pump internal repairs. IMA assistance is generally required to perform repairs to pump casings and occasionally to machine wearing rings, shafts, and impellers.

Maintenance actions related to the firepump ball bearings accounted for 16 of the 171 significant maintenance actions reported against the firepumps. Only one of the JCNs requested IMA assistance. A total of 363 ship's force man-hours were reported, for an average of 23 man-hours per JCN. Discussions with ship personnel revealed that ship's force is normally capable of replacing bearings without outside assistance.

CASREP data showed that 1 CASREP requesting various internal repairs was submitted against a firepump of the LHA-1 Class during the period 1 January 1976 through 22 April 1981. The LPH-2 Class submitted 14 CASREPs requesting various internal repairs to the firepumps during the period 1 January 1978 through 22 April 1981. Appendix C presents the CASREP summary, including the reasons for the CASREPs, ships that reported CASREPs, and downtime hours. Seven ships submitted CASREPs associated with firepump internal repairs. The average CASREP frequency for internal repairs is approximately one CASREP every 22 ship operating months for each ship addressed in this analysis.

Three CASREPs reported a total of 3,154 downtime hours awaiting parts. CASREP data revealed that no specific part was ordered repeatedly. There were 16,859 downtime hours due to maintenance, an average of 1,204 hours (50 days) per internal repair CASREP, attributable primarily to ship's force personnel awaiting IMA assistance to complete the repairs. All of the CASREPs listed a C-2 severity, indicating a minor degradation of a primary mission area. Although there have been CASREPs for firepumps, it appears that the loss of one firepump did not significantly degrade the FMS.

Under the DART Program (MIL-P-1739D), there is a firepump improvement program that is applicable to all ships of the United States Navy. The principal problems associated with the centrifugal firepumps were identified by the program as erosion and corrosion of the cast gun-metal pump casings and deterioration of the casing wearing rings. As a result of the DART Program, steps were taken to alleviate these problems by procuring stainless steel casings and monel wearing rings and revising the military specifications for future procurement of firepumps. Revisions were made to the following material specifications for manufacturers of salt-water firepumps:

- Stainless steel casings and impellers
- Monel casing wearing rings
- Ringless impellers
- Mechanical seals

Portions of the DART Program for firepumps have been implemented on the LHA-1 and LPH-2 Class ships. Shipalt LPH-0428D was developed to modify the 1,000-GPM firepumps to accept mechanical seals. As mentioned in Section 3.2.1.1, ship personnel experience with the mechanical seals has not been favorable. Monel casing wearing rings and stainless steel impellers have apparently been successful in reducing pump casing and impeller problems. Ship personnel suggested that the casings be changed to stainless steel because the cast casings currently installed have been corroding.

Applicable maintenance index pages (MIPs), listed in Appendix F, were reviewed for the electric-motor-driven and turbine-driven firepumps. One of the PMS requirements is performance of an internal firepump inspection either annually (A) or cyclically (C), depending on the particular MIP. Because of the uneven utilization of the firepumps, it is not practical to have a regularly scheduled opening and inspection of all firepumps. Ship personnel expressed the opinion that unless a pump failure is anticipated or a problem suspected, opening of a pump is not warranted. Therefore, it is recommended that the annual (A) or cyclic (C) open-and-inspect PMS requirement for the electric-motor-driven and turbine-driven firepumps be changed to a situational requirement. For example, if the firepump vibrates excessively, is abnormally noisy, or produces low output, an internal inspection should be performed.

The data reviewed indicated that most of the failures are a result of normal wear and tear and that intracycle corrective maintenance actions will probably be required more frequently on the firepumps that are used most.

3.2.1.3 Complete Pump Overhaul

There were 18 JCNs reported in the MDS narratives requesting complete or class B pump overhaul. They account for 10.5 percent of the total significant maintenance actions for the firepumps. Complete overhauls include disassembling the firepump and renewing all or most internal parts such as casing and impeller wearing rings, throat bushings, bearings, and shaft sleeves; repairing the casing; straightening the shaft; balancing the rotor assembly; reassembling the firepump with new studs and nuts; and then performing an operational test.

The MDS narrative data classified as representing firepump overhauls were not as consistent as the other maintenance action classifications. Two JCNs, or 11 percent of the total number of overhaul JCNs, reported 39 IMA man-hours. There were 630 ship's force man-hours reported: 534 man-hours for five completed firepump overhauls accomplished by ship's force, averaging 107 man-hours per overhaul, and 96 man-hours for ship's force testing of the firepumps. Depending on availability, capability, and facilities, different maintenance levels were chosen (i.e., designated on the JCN as the preferred level) to accomplish the firepump overhauls. The depot level was chosen to do six; ship's force, four; and the IMA, three. None of these overhauls were completed as of the end of the data period analyzed.

Ship's force personnel reported that they are normally capable of accomplishing major internal repairs on firepumps, but outside assistance is usually requested for class B overhauls and casing and impeller repairs. Ship's force personnel said that they would prefer to overhaul the firepumps themselves, since past experience with shipyard- and IMA-assisted overhauls (in their opinion) had not been up to expected standards, but the higher level of capability and facilities provided by a shipyard or IMA was sometimes needed to complete the required repairs.

A review of recent authorized SARPs shows that approximately 60 percent of the firepumps have historically received a class B overhaul during regular ship overhauls at a shipyard -- about every five years. MDS and CASREP data indicated that the most frequently used firepumps also required intracycle major internal repairs as a result of normal wear and tear.

As mentioned earlier, the firepumps receive disproportionate use and, as a result, do not deteriorate at the same rate with respect to calendar time. Because of this, routine overhaul of all firepumps during ROH is not warranted. It is therefore recommended that the determination of whether a firepump should receive class C repairs or a class B overhaul during ROH be based on POT&I or MCA inspection results. Operational and vibration tests should be performed concurrently with MCA inspection to determine the extent of needed shipyard repairs.

A review of repair profiles, EOC task summaries, MDS data, and available SARPs for the ship classes under study, as well as for other ship classes with similar equipment, disclosed an average man-day burden for the above tasks (class C repairs, class B overhaul). It was determined that class C repairs for one firepump normally require an average of 18 depot-level man-days and class B overhaul requires an average of 44 depot-level man-days per firepump. The average man-hours for class C repairs provides for the repair or replacement of any or all of the following: the bearings, wearing rings, casing, shaft, rotor assembly, and impeller. It is expected that some installed firepumps will require no repairs or relatively simple repairs, while others will require more extensive work.

3.2.1.4 Corrosion

The data reported by LHA-1 and LPH-2 Class ships were reviewed for any indication of corrosion problems in the FMS. Past analyses on other ship classes have shown that corrosion is traditionally a significant problem in pump rooms and machinery rooms. Corrosion is caused by several factors: a large number of equipments confined in a small area; poor ventilation, with resulting condensation; direct reaction of poorly preserved metal surfaces with oxygen in the air; and steam and salt water leakage. Surprisingly, ship visits and the available data did not find corrosion of the FMS on the LHA-1 and LPH-2 Class ships to be a significant problem. Ship's force personnel expressed the opinion that routine maintenance and preservation of the equipment should limit the spread of corrosion.

Although there were no signs of excessive corrosion, it appeared that pump foundations, bedplates, and fasteners were most susceptible to corrosion due to salt water leakage. In order to reduce the number of ship's force man-hours devoted to preservation of these areas, it is recommended that NAVSEA-approved corrosion-control techniques be applied to these susceptible areas. Wire sprayed aluminum and low- or high-temperature sealer or polyamide epoxy coating (where temperatures permit) are the approved coatings for use on machinery foundations and bedplates, and ceramic-coated fasteners are approved for foundation bolts. Appendix E provides a detailed description of the applicable corrosion-control techniques.

3.2.1.5 Maintenance Strategy

The results of this analysis have shown that the firepumps are likely to require major corrective maintenance during the operating cycle. The most commonly reported failure mode was deterioration of internal parts from normal use. There are many variables to consider in trying to predict the frequency of internal repairs, e.g , operating error, parts quality, previous maintenance quality, and rate of usage; therefore, it is impossible to predict a valid calendar-time-based interval between firepump failures or maintenance actions.

In 100 percent of the firemain and flushing system CASREP submissions reviewed, a severity code of C-2 was assigned. C-2 represents minor system degradation, indicating that the significance of a single firepump failure is relatively low. This is substantiated by the fact that only two or three out of eight firepumps are normally required to maintain firemain pressure. Since redundancy is built into the firemain system and all firepump repairs are normally within the capability of either ship's force or an IMA, it is concluded that an on-condition maintenance strategy should be adopted for firepumps during the operating cycle.

Since it is impossible to predict a valid calendar-time-based interval between overhauls that is applicable to all installed firepumps, it is recommended that the firepumps receive either class C repairs or class B overhaul, as determined by CSMP, POT&I, or MCA inspection, during future shipyard ROHs. Operational and vibration tests should be performed concurrently with MCA inspection to determine the extent of needed shipyard repairs.

Another result of the uneven utilization of the firepumps is the impracticality of performing a regularly scheduled open-and-inspect task in accordance with current, applicable MIPs. Unless a pump failure is anticipated or a problem suspected, opening of a pump is not warranted. Therefore, it is recommended that the annual (A) or cyclic (C) open-and-inspect PMS requirement for the electric-motor-driven and turbine-driven firepumps be changed to a situational requirement.

3.2.1.6 Recommendations

It is recommended that the following actions be taken with respect to the firepumps installed on the ship classes analyzed:

- Change periodicity of the inspection of internal parts from annual (A) or cyclic (C) to situation requirement (R) for the applicable MIPs listed in Appendix D.
- Follow PMS in respective MIPs, with the changes recommended by this analysis.
- Use an on-condition intracycle maintenance strategy, with ship's force and IMA repairs or overhauls as required for the firepumps.
- Perform class C repairs or class B overhaul on selected firepumps during regular ship overhaul on the basis of CSMP, the results of POT&I, or MCA tests and inspections. In addition, develop material condition assessment standards that will better differentiate between the need for class B overhaul and class C repairs.

3.2.2 Firepump Motors

The MDS data showed that the maintenance man-hour burden associated with the AC motors accounted for 15,056 man-hours, or 37 percent of the total man-hour burden for the selected firemain system APLs. A total of 236 JCNs were reported against the AC motor APLs reviewed, and 101 JCNs (43 percent of the total) are considered to be significant maintenance actions on the AC motors. These JCNs account for 12,183 man-hours, or 81 percent of the total man-hours reported. Table 3-4 summarizes the significant maintenance actions for the firepump motors. These are discussed in the following subsections. Only one JCN (four ship's force man-hours) was reported against LHA-1 Class ships, and it was not considered to be a significant maintenance action. The firepump motors on the LHA-1 Class ships have not yet contributed any significant maintenance burden; however, they have not accumulated a significant number of operating hours.

Table 3-4. SUMMARY OF SIGNIFICANT FIREPUMP MOTOR MAINTENANCE ACTIONS

Maintenance Action or Failure Mode	Total JCNs	JCNs Reporting IMA Assistance	Man-Hours		
			Ship's Force	IMA	Total
Balance Rotor Assembly	7	2	196	499	695
Shaft Repairs/Replacements	13	10	553	1,949	2,502
Bearing Replacements	36	8	1,498	377	1,875
Motor Rewind	45	30	1,791	5,320	7,111
Totals	101	50	4,038	8,145	12,183

Note: No JCNs were reported by LHA-1 Class ships.

3.2.2.1 Shaft Repair/Replacement

Thirteen JCNs reported that the shaft needed replacement or repair. Ten of those JCNs requested IMA assistance, for a total of 1,949 IMA man-hours, or an average of 195 man-hours per JCN. There were 553 ship's force man-hours, an average of 43 hours per JCN. Compared with the results of similar analyses previously conducted on the firemain and flushing system of other ship classes, these man-hour figures appear to be very high. In the most recent analysis conducted on the same types of motors, shaft repair or replacement required, on the average, 9 ship's force man-hours and 89 IMA man-hours per JCN. Either new shafts were built or unreported maintenance actions were included in the reported man-hours for shaft repair and replacement. The IMA is capable of rebuilding or straightening the shaft. A vibrating motor was the most common reported symptom of the need to replace or repair (i.e., balance and straighten) the shaft. During the CASREP data period, only two CASREPs were submitted for damaged shafts, and they were the result of worn bearings. Both casualties were reported as C-2 severity.

3.2.2.2 Rewinds/Bearing Replacement

MDS data showed that 45 JCNs were reported for firepump motor rewinds, with a total of 1,791 ship's force man-hours expended, for an average of 40 hours per JCN. Sixty-seven percent (30) of the JCNs reported IMA assistance, which accounted for 5,320 man-hours, or an average of 177 IMA man-hours expended each time IMA assistance was reported.

Rewinds are most commonly a result of a moist environment that causes the motor to short to ground. The ship's force man-hours and IMA man-hours are not expended solely on rewinding. When a motor is rewound, it is also dipped and baked, and the bearings are replaced (bearings are normally replaced every time the motor is opened). Ship's force personnel aboard the LPH-2 Class ships said that they are capable of rewinding, dipping, and baking the motors but that, because they are often over-burdened, IMA assistance is frequently requested. The firepump motors aboard the LHA-1 Class ships are much larger than those installed on LPH-2 ships, and LHA-1 Class ships do not have the capability of rewinding, dipping, and baking those motors.

Seventeen C-2 severity CASREPs reported motors shorted because of insulation breakdown in the stator windings or moisture accumulation, requiring rewinds. Appendix C presents the CASREP summary data. Only one CASREP was reported by an LHA-1 Class ship. The average CASREP periodicity for LPH-2 Class ships was calculated by dividing the ship operating years (SOY) during the CASREP data period (17.89) by the number of CASREPs (16). Thus the average CASREP periodicity for motor rewinds is approximately one CASREP every 1.1 ship operating years for the LPH-2 Class.

Three CASREPs reported a total of 5,076 downtime hours attributed to supply. The parts required were not listed in the CASREPs, and thus it was not possible to determine if a change should be made in the stocking levels.

There were 14,404 downtime hours due to maintenance, corresponding to an average of 847 hours (35 days) per grounded-motor CASREP. The large number of downtime hours highlights the fact that the loss of one firepump motor (and therefore, firepump) is not critical to the mission areas of the ship.

MDS data showed that 36 JCNs were reported for firepump motor bearing replacements. There were 1,498 ship's force man-hours expended, for an average of 42 hours per JCN. Twenty-two percent (8) of the JCNs reported IMA assistance, accounting for 377 IMA man-hours, an average of 47 IMA man-hours per JCN.

A review of MDS and CASREP data revealed that worn or failed bearings were normally reported to be the result of normal wear and tear or an unbalanced rotor assembly.

Ship's force personnel are capable of replacing the bearings; however, they do not have the capability to balance the rotor assembly. IMA assistance is often requested when the rotor assembly requires balancing concurrently with bearing replacement.

Eight CASREPs requiring bearing replacements were submitted against the LPH-2 Class during the CASREP data period. Again, no CASREPs were reported against the LHA-1 Class. The average CASREP periodicity for bearing failures was found to be one CASREP every 2.2 ship operating years for the LPH-2 Class.

There were no downtime hours due to supply, because bearings are readily available. There were 8,208 downtime hours due to maintenance, corresponding to an average of 1,026 hours (43 days) per bearing-repair CASREP. All of the CASREPs listed a C-2 severity, indicating a minor degradation of a primary mission area. As it is for the firepumps, the significance of a single firepump motor failure is relatively low. The amount of redundancy in the firemain system could explain the large amount of downtime, the majority of it being expended waiting for a convenient time to perform the required maintenance.

The occurrences of motor shorts and bearing failures were determined to be random. Motor shorts are normally caused by unpredictable environmental factors, and bearing failures are most commonly a result of normal wear and tear.

Applicable MIPs for the ac motors were reviewed. The maintenance requirements specify bearing lubrication at various intervals and an annual cleaning and inspection of the ac motors. Existing PMS requirements are judged to be effective, and they should continue to be accomplished as scheduled.

3.2.2.3 Overhauls

No JCNs reported specifically required an overhaul of the firepump motors; however, review of SARP data indicated that approximately 55 percent of the firepump motors received a class B overhaul during regular shipyard overhauls, about every five years. Like the firepump, the motors experienced unequal use; as a result, it is not practical to routinely perform class B overhauls on all motors during ROH.

Ship's force, assisted as necessary by an IMA, is capable of performing most significant repairs (rewinds, shaft and bearing replacements/repairs) on the firepump motors on a situational-requirement basis during an operating cycle. Ship's force personnel concur that the need for firepump motor repairs or class B overhauls during future ROHs should be determined on the basis of POT&I results and CSMP.

A review of repair profiles, EOC task summaries, and available SARPs for the ship classes under study, as well as other ship classes with similar equipment, disclosed an average historical maintenance burden for class C repairs and class B overhaul. Class B overhauls are estimated to require

27 depot-level man-days; class C repairs, 6 organizational-level man-days and 7 IMA-level man-days.

3.2.2.4 Maintenance Strategy

The analysis has shown that the firepump motors are likely to require some corrective maintenance during an extended operating cycle. The usage rates of firepump motors, like those of the pump ends, are unequal, and the interval at which bearings will fail is somewhat dependent on the rate at which total operating hours are accumulated. Motor rewind requirements are impossible to predict, since they are usually caused by environmental factors, particularly moisture, which have little or no correlation with operating-hour accumulation. The experience of ship's force personnel has shown that a constantly used motor will require rewinding and bearing replacement about three times during the operating cycle. Even if this is true, it is still impossible to establish a precise maintenance interval based on calendar time that will apply to all of the motors. It is therefore concluded that an on-condition maintenance strategy should be adopted for the firepump motors during the operating cycle.

It is further recommended that the need for motor repairs or class B overhauls during future ROHs be determined on the basis of POT&I results or CSMP.

3.2.2.5 Recommendations

It is recommended that the following actions be taken with respect to the firepump motors:

- Use an on-condition maintenance strategy for firepump motors.
- Follow PMS as shown on applicable MIPs for the ac motors. No changes are recommended.
- Perform class C repairs or class B overhauls of firepump motors, as determined to be necessary by POT&I or CSMP, during future shipyard availabilities.

3.2.3 Firepump Turbines

The MDS data showed that the maintenance man-hour burden associated with the steam turbines accounted for 5,009 man-hours, or 12 percent of the total man-hour burden reported against the selected firemain and flushing system APLs. A total of 164 JCNs were reported against the APLs reviewed; 41 JCNs, or 25 percent of the total, are considered to represent significant maintenance actions on the steam turbines. Significant maintenance actions account for 2,951 man-hours, or 59 percent of the total man-hours reported. Although only 31 JCNs and 297 maintenance man-hours were reported by LHA-1 Class ships, the failures and maintenance actions reported are similar to those reported by LPH-2 Class ships and are included in all calculations. The smaller number of maintenance actions reported by the LHA-1 Class was attributed primarily to the fact that the Class is relatively new and has not accumulated significant operating time.

Discussions with LHA-2 personnel revealed that their steam-turbine-driven firepumps were not nearly as efficient as their motor-driven firepumps, and therefore have been used a total of only 16 hours since the ship's commissioning. It has been their experience that it requires two turbine-driven firepumps to maintain the same firemain system pressure that can routinely be maintained by one motor-driven firepump. Since the pump ends are identical, logic dictates that the difference must be in some aspect of the driver. Ship's force personnel indicated that the cause of this deficiency is unknown but is currently under investigation. During this analysis, review of MDS data did not indicate that any other ship was having this problem. Table 3-5 summarizes the significant maintenance actions identified for the turbines. They are discussed in the following subsections.

Table 3-5. SUMMARY OF SIGNIFICANT FIREPUMP STEAM TURBINE MAINTENANCE ACTIONS

Maintenance Action or Failure Mode	Total JCNs	JCNs Reporting IMA Assistance	Man-Hours		
			Ship's Force	IMA	Total
Speed-Limiting Governor	5	2	186	489	675
Carbon Seals	6	1	157	54	211
Pressure Regulator	8	4	429	140	569
Thrust and Journal Bearings	8	1	663	144	807
Turbine Valves	14	10	182	507	689
Totals	41	18	1,617	1,334	2,951

3.2.3.1 Speed-Limiting Governor

A review of the MDS data reported on the firepump steam turbines revealed that there were 5 JCNs reporting significant maintenance actions against the speed-limiting governors. Two of these JCNs included IMA assistance, totaling 489 IMA man-hours. On the average, 244 IMA hours were expended each time assistance was requested. Reported ship's force man-hours totaled 186, an average of 37 man-hours per JCN, for maintenance of the speed-limiting governors during the data period.

According to ship personnel, IMA or technical assistance is routinely requested when a governor must be overhauled, because of inadequate training of ship's force personnel, although they are capable of replacing worn or broken parts.

Applicable PMS MIPs for the steam turbines enumerate various requirements, but the majority of the MIPs specify a weekly lubrication and a monthly test of the speed-limiting governor. If any erratic operation, such as overspeeding of the turbine, is noticed, the speed-limiting governor should be examined further. Review of available SARPs showed that the speed-limiting governors were normally overhauled, together with the associated turbine, during ROH. No CASREPs were reported against the speed-limiting governors. On the basis of that fact and the low number of JCNs reported, it is concluded that the PMS requirements for the speed-limiting governors are sufficient, and no changes are recommended.

3.2.3.2 Carbon Seals

The MDS data showed 6 maintenance actions (JCNs) reported against the carbon seals on the steam turbines. One of the JCNs requested IMA assistance, for a total requirement of 54 IMA man-hours. There were 157 ship's force man-hours reported, for an average of 26 man-hours per JCN. These data show that the man-hour burden for carbon seal maintenance has been low. When carbon seals wear out and start leaking, they must be replaced. Ship's force is normally capable of replacing carbon seals without outside assistance. No CASREPs were reported against the steam turbine carbon seals.

The applicable PMS requirements for the steam turbines specify that the internal parts be inspected cyclically, usually about every five years. This requirement is judged to be prudent and should be continued.

3.2.3.3 Pressure Regulator

A review of MDS data reported on the steam turbines showed 8 significant maintenance actions (JCNs) reported for pressure regulator malfunctions. Four, or 50 percent, of the JCNs requested IMA assistance, totaling 140 IMA man-hours. An average 35 IMA man-hours were expended each time assistance was requested. There were 429 ship's force man-hours expended on the pressure regulators -- an average of 54 hours per significant maintenance action.

The principal failure modes reported for the pressure regulators were excessive cycling, leaking at the gaskets, and worn internal parts. Ship's force personnel indicated that they were capable of performing the majority of repairs needed, but IMA assistance was routinely requested when the pressure regulator required overhauling or the pressure gauges had to be calibrated. The outside assistance was requested for pressure regulator overhaul because any machining or rebuilding of the pressure regulator internal surfaces requires not only skilled personnel but precise knowledge of the original dimensions as well. Review of past SARPs revealed that the pressure regulator is normally overhauled during ROH.

PMS specifies an annual cleaning and inspection of the pressure regulator. This work should also be accomplished during the intracycle if the regulator fails to maintain automatic control of the equipment.

There were no CASREPs reported against the pressure regulator. On the basis of the absence of CASREPs and the low number of JCNs reported, it is concluded that the PMS requirements for the pressure regulator are sufficient, and no changes are recommended.

3.2.3.4 Bearings

Eight JCNs were reported for maintenance of the thrust and journal bearings on the steam turbines. Only one of the JCNs requested IMA assistance for other repairs needed as a result of worn bearings. There were 663 ship's force man-hours, an average of 83 hours per JCN reported against the bearings. The man-hours are significantly higher than similar calculations made on other ship classes with like equipment (i.e., 83 versus 26 ship's force man-hours per JCN). It appears that other maintenance was included in the JCNs reporting journal and thrust bearing replacement. Therefore, the 26-hour average repair time per JCN is considered to be more appropriate.

The failure modes reported for the steam turbine bearings are the same as those reported for the firepump bearings and motor bearings. The bearings become worn beyond allowable clearances and must be replaced. The symptom of worn bearings is commonly excessive shaft vibration or change in the position of the rotor. If the lube oil overheats, the bearings should be examined for evidence of wiping. Ship's force is capable of making the bearing repairs, but IMA assistance is sometimes requested when some subsequent and more serious damage occurs as a result of worn bearings. For example, IMA assistance was requested when the turbine casing needed machining, the rotor needed balancing, or the shaft needed aligning.

No CASREPs were reported for steam turbine thrust or journal bearing failures.

The PMS requirements concerning the bearings on steam turbines include an annual inspection of the shaft journal bearings, bearing oil slingers, bearing oil seals, and thrust ball bearings; a cyclic internal inspection; and a routine task to sample and inspect the lube oil for cleanliness. As a result of the low number of JCNs and absence of CASREPs, it is concluded that the existing PMS requirements are sufficient and should be continued.

3.2.3.5 Steam Turbine Valves

A review of the MDS data reported on the steam turbines revealed that there were 14 JCNs reporting significant maintenance actions against the combination exhaust/relief valves, steam admission valves, or governor valves. Ten of the JCNs, or 71 percent, requested IMA assistance. There were 507 IMA man-hours expended on the valves, for an average of 51 IMA man-hours per JCN requesting assistance. There were 182 reported ship's force man-hours, or an average of 13 man-hours per JCN, for valve repairs.

The two principal failure modes were deterioration and leakage of the steam turbine valves. The MDS data revealed that IMAs perform the majority of valve repairs and replacements. Ship's force man-hours were accumulated through performance of routine tests and inspections and minor repairs to the valves.

Three C-2 CASREPs were prepared on the combination exhaust/relief valves on the steam turbines. Two of the CASREPs had not been CASCORED (completed) and therefore had no reported supply or maintenance downtime hours. The third CASREP indicated 320 hours (13 days) of downtime due to supply, and a total of 3,164 hours (132 days) due to maintenance. However, the maintenance hours reported also included additional work on the governor valve stem and are probably an indication that the maintenance was not promptly performed because the failure did not have a major adverse effect on the system.

PMS for steam turbines specifies a quarterly test on the combination exhaust/relief valve, and SARP analysis determined that all of the valves are normally overhauled during ROH.

Review of MDS data and CASREPs led to the conclusion that failures have occurred and will continue to occur randomly and infrequently. As a result, the prediction of a particular interval at which scheduled steam turbine valve maintenance should be performed is not feasible, and an on-condition maintenance strategy is recommended. In view of the small number of maintenance actions, it is also concluded that the existing PMS is sufficient, and no changes are recommended.

3.2.3.6 Maintenance Strategy

The results of this analysis have shown that the firepump steam turbines have been subjected to few major corrective maintenance actions during the operating cycle. Intracycle maintenance actions, when required, were accomplished primarily by ship's force, with some IMA assistance as necessary.

The review of available SARPs indicated that approximately 90 percent of the firepump turbines (including pressure regulator) aboard the LPH-2 Class ships were routinely overhauled during ROH. The two SARPs available for the LHA-1 Class ships indicated that only 50 percent of their firepump turbines were overhauled (as mentioned in Section 3.2.3, the turbine-driven firepumps aboard the LHA-2 are rarely used). There was no evidence to suggest that the firepump steam turbines should routinely receive class B overhaul during ROHs. It is therefore recommended that the need for firepump turbine repairs or class B overhaul during ROH be determined on the basis of POT&I results, CSMP, or MCA inspection. When either class C repairs or class B overhaul of the turbine are determined to be necessary during an ROH, it is recommended that the work be accomplished by an industrial activity because of its special facilities and more experienced personnel. Routine operating cycle repairs can normally be accomplished by ship's force personnel with occasional IMA assistance. In addition, removal of the entire turbine assembly, including bedplate, to an industrial repair shop when class B overhaul is required permits a thorough inspection of the turbine and facilitates ship's force preservation of the foundation and surrounding area. From the review of SARPs and repair profiles, it is estimated that, on the average, 76 depot-level man-days are needed for a class B overhaul of a firepump turbine. Class C repairs are estimated to require approximately 13 depot-level man-days and 3 organizational-level man-days.

Historical data indicate that if existing PMS requirements are adhered to, the turbine should operate satisfactorily during the period from ROH to ROH, with only minor corrective maintenance actions. Therefore, an on-condition maintenance strategy is recommended for the firepump turbines.

3.2.3.7 Recommendations

It is recommended that the following actions be taken with respect to the firepump turbines:

- Adopt an on-condition intracycle maintenance strategy for the firepump turbines.
- Perform class B overhaul or class C repair of the steam turbines and pressure regulator during regular ship overhaul as determined to be necessary by POT&I, CSMP, or MCA inspection.

3.2.4 Valves

The MDS data revealed a maintenance burden of 16,290 man-hours associated with the firemain system valves, representing 28 percent of the total man-hour burden reported against the selected firemain system APLs. There were 1,250 JCNs reported against the firemain valves.

There were 8,831 ship's force man-hours reported, or approximately 7.0 ship's force man-hours per JCN; there were 7,459 IMA man-hours reported against various valve APLs. Because of the large number of JCNs, IMA actions were not separately identified. Two major failure modes and maintenance actions associated with all of the valves were identified: a deterioration of the valves from the circulation of salt water throughout the firemain system, and valve leakage attributed to normal deterioration. Ship's force, with some IMA assistance, is capable of performing the necessary intracycle maintenance actions on valves, since both ship's force and IMA personnel are capable of repairing or replacing most of the valves in the firemain system. During ROH, the firemain system is routinely drained and flushed and the valves are overhauled by the shipyard. The only valve repairs that are normally deferred are those related to sea suction valves. It is difficult to repair the sea suction valves while the ship is in the water, and so when possible, the repairs are deferred until the ship is in drydock.

Six CASREPs were prepared against firemain system valves during the CASREP data period. One CASREP reported downtime hours due to supply. A total of 4,421 downtime hours due to maintenance were reported by 5 of the 6 CASREPs. One CASREP for the LPH-2 Class reported no downtime hours, because it had not yet been CASCORED. Because of the cross-connecting capabilities within the FMS, loss of a single valve is not normally significant. All of the CASREPs were reported at the C-2 severity level.

Valve repairs or replacements were the most frequent maintenance actions; there were approximately 20 actions per ship per operating year for both ship classes. The man-hour average varied, as it did for the other major components. The average ship's force man-hours devoted to FMS valve repairs per ship operating year were 84 and 166 for the LHA-1 Class and LPH-2 Class, respectively. The average IMA man-hours per ship per operating year were 104 and 140 for the LHA-1 Class and LPH-2 Class, respectively.

Ship's force personnel aboard the LPH-7 reported that they are planning to change all of the butterfly valves to gate valves where appropriate in the firemain system. Some of the butterfly valves have already been changed to gate valves and according to ship's force personnel, have proven to represent a smaller maintenance burden. In addition, the ship reported that good boots for the butterfly valves have been difficult to obtain through the Navy supply system.

Personnel aboard the LHA-2 reported that the most significant maintainability problem in the firemain system is the hydraulic valve actuators. Some of the valves of the FMS are installed upside down (i.e., the hydraulic actuator is underneath the valve). If the valve develops a leak, the salt water drips down on the actuator and corrosion results. A solution to the problem would be to rotate the actuator so that it was not vertically below the valve. Unfortunately, this might not be possible in some cases, because the location of the piping around the valve could prohibit any adjustment of position of the valve and actuator. It is recommended that the cognizant technical code analyze this problem and determine the appropriate solution.

3.2.4.1 Maintenance Strategy

It is recommended that an on-condition maintenance strategy be continued for the firemain system valves. Ship's force and IMA personnel are normally capable of making firemain system valve repairs; however, depot assistance is usually requested when a sea suction valve must be replaced. Review of available SARPs showed that the firemain system is routinely chemically flushed and selected valves are normally overhauled during ROH by the industrial activity. From the SARP review and historical repair profile, it is estimated that, on the average, 335 man-days per ship are normally expended during ROH in repair and overhaul of FMS valves. Calculations based on the IMA maintenance burden for the FMS valves and piping from Table 3-2 show that approximately 112 IMA man-hours per ship operating year are typically required to support FMS maintenance. This conforms closely to previous IMA estimates developed as part of the EOC summary, i.e., 120 man-hours of IMA support per year. The on-condition maintenance strategy, accomplishment of existing PMS, the provision of approximately 112 IMA man-hours per year, and the continuation of depot flushing of the firemain system and overhaul of selected valves during ROH should adequately maintain the system.

3.2.4.2 Recommendations

It is recommended that the following actions be taken with respect to the firemain and flushing system valves:

- Continue an on-condition maintenance strategy for the FMS valves.

- Have the cognizant NAVSEA technical code investigate the reported problem of improperly positioned hydraulic valve actuators, leading to actuator corrosion problems.

3.3 COUNTERMEASURE WASHDOWN SYSTEM (WDS)

MDS, CASREP, and SARP data for the LHA-1 and LPH-2 Classes were reviewed, and it was determined that the washdown system did not represent a significant maintenance burden to the ships involved in this analysis. No CASREPs were reported against the WDS, and the most common maintenance actions reported in the MDS data were repair or replacement of valves and piping. Ship's force with occasional IMA assistance is capable of accomplishing all of the maintenance actions required for the washdown system.

Discussions with ship personnel revealed that deterioration and corrosion of the steel piping exposed to weather is prevalent. It is recommended that NAVSEA-approved wire sprayed aluminum (WSA) coating or polyamide epoxy coating (MIL-P-24441) be applied to the piping. The pipe hangers can also be treated with these coatings. It is recommended that the fasteners be treated with ceramic coating (MIL-C-81751) or replaced with CRES fasteners. Appendix F contains recommended, approved corrosion-control techniques.

Applicable PMS MIPs require monthly or quarterly cleaning, inspection, and testing of the control valves and washdown system. On the basis of the small number of repairs, it is concluded that the PMS requirements for the countermeasure washdown system are sufficient, and no changes are recommended.

An on-condition maintenance strategy is recommended for the washdown system. The equipment in the washdown system, such as valves, piping, fittings, and spray nozzles, will require some maintenance during the operating cycle as a result of normal wear and tear. However, on such a large system, with many different pieces of equipment, it is impossible to establish precise maintenance intervals for specific components.

Neither the results of ship visits nor review of MDS data give any indication that the washdown system is likely to be the source of a significant maintenance burden. The few repairs that will be required can be readily accomplished by ship's force personnel with occasional IMA assistance. Adherence to existing PMS procedures and application of an on-condition maintenance strategy should adequately support the washdown system during the operating cycle. Any industrial repairs during ROH should be identified on the basis of POT&I results or CSMP. The routine authorization of washdown system repairs during ROH is not warranted and is not recommended.

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

The following conclusions resulted from this analysis:

- Most repairs to the equipments of the firemain, flushing, and washdown system can be accomplished by ship's force personnel with occasional IMA assistance.
- Unequal use of the firepumps and their drivers is relevant to the maintenance burden associated with individual firepumps.
- Ship's force and IMAs are capable of accomplishing most major repairs to the firepumps, motors, and steam turbines. Depot-level assistance is normally requested for turbines when a class B overhaul is required, because of the depot's special facilities and more experienced personnel.
- Time-directed class B overhaul of the firepumps and drivers during regular shipyard overhaul is not a practical maintenance strategy.
- Either class C repairs or class B overhaul should be performed on the firepumps, motors, and steam turbines during ROH, as determined to be necessary by POT&I results, CSMP, or MCA inspection.
- An on-condition maintenance strategy is most appropriate for the firepumps and their drivers.
- A change in the periodicity of the annual or cyclic PMS open-and-inspect task to a situational requirement for the firepumps would be advantageous.
- With only minor changes, the PMS requirements for the firemain, flushing, and washdown system are adequate.

4.2 RECOMMENDATIONS

Recommendations for corrective and restorative maintenance requirements that are to be accomplished by depots or IMAs are summarized in Table 4-1. These recommended tasks are based on the findings and conclusions of

Table 4-1. RECOMMENDED IMA AND DEPOT CORRECTIVE AND RESTORATIVE ACTIONS

Task Number			Component or System	Unit Quantity per Ship	Task Description	Level of Repair	Repair Estimate per Unit	Task Frequency* (Months)	Reference Section
Task Type	5-Digit SWAB	Number							
E	521-1	1	Firemain System Valves	Var.	Chemically flush the FMS and overhaul selected values as determined to be necessary by POT&I results or CSMP.	Depot	335 man-days	60	3.2.4
E	521-2	2	Firepumps	8	Perform class B overhaul of the firepumps as determined to be necessary by CSMP, POT&I, and MCA inspection.	Depot	44 man-days	120	3.2.1.3
E	521-2	3	Firepump Motors	4 on LHA-1 6 on LPH-2	Perform class B overhaul of the firepump motors as determined to be necessary by CSMP or POT&I results.	Depot	27 man-days	120	3.2.2.3
E	521-2	4	Firepump Steam Turbines	4 on LHA-1 2 on LPH-2	Perform class B overhaul of the firepump steam turbines as determined to be necessary by POT&I results or CSMP.	Depot	76 man-days	120	3.2.3.6
Q	521-2	5	Firepumps	8	Perform class C repairs on firepumps on the basis of condition.	IMA	30 man-hours	12	3.2.1
Q	521-2	6	Firepump Motors	4 on LHA-1 6 on LPH-2	Perform class C repairs on firepump motors on the basis of condition.	IMA	30 man-hours	12	3.2.2
Q	521-2	7	Firepump Steam Turbines	4 on LHA-1 2 on LPH-2	Perform class C repairs on firepump steam turbines, pressure regulators, and speed-limiting governors	IMA	15 man-hours	12	3.2.3
Q	521-1 523-1	8	Washdown System FMS Valves	Var.	Assist ship's force with intracycle valve and piping repairs on the basis of condition.	IMA	120 man-hours	12	3.2.4 3.3

*Refer to Section 4.2 for definition of task frequency relationship to task type.

this analysis and represent best engineering judgment. Comparisons may therefore differ in some respects with historical experience. The recommended maintenance requirements should be incorporated in the LHA-1 Class and LPH-2 Class CMPs. The types of maintenance tasks are categorized as follows:

- E Tasks - Engineered work items that should be carefully considered for accomplishment at the proposed frequency to enable the ship to fulfill its mission. The tasks result from either a long history of experience in system operation or a System Engineering Analysis. The E tasks are generally limited to the ship's critical systems.
- R Tasks - Routine work items accomplished whenever the opportunity is presented (such as drydock work) or work performed repetitively to support industrial work such as staging, temporary services, and technical support.
- M Tasks - Mandatory work items accomplished to comply with NAVSEA and Type Commander instructions.
- I Tasks - Inspections performed to comply with NAVSEA or Type Commander Instructions.
- T Tasks - Tests or inspections performed during one maintenance availability in order to define maintenance requirements to be performed during a subsequent availability. T tasks may also include certain tests/inspections to be performed during the operational period prior to the start of a scheduled maintenance availability.
- Q Tasks - Qualified estimates consisting of all maintenance actions to be performed on condition. These estimates represent a reservation for manpower and generally are related to the accomplishment of corrective maintenance.

Other improvements to the firemain system equipments are categorized as follows:

- Design Improvements
  - Recommended shipalts, ordalts, and field changes
  - Recommended equipment redesign or replacement
- Maintenance Strategy Improvements
  - PMS changes
  - Policy
- Support Improvements
  - ILS improvements
  - Maintenance-capability improvements
- Other

These recommended improvements are summarized in Table 4-2.

Table 4-2. RECOMMENDED IMPROVEMENTS			
Component	Number	Recommendation	Reference Section
Maintenance Strategy Improvements - PMS Changes			
Firepumps	1	Change periodicity of the inspection of internal parts from an annual (A) or cyclic (C) to a situational requirement (R) for the applicable MIPs listed in Appendix D.	3.2.1.2
Maintenance Strategy Improvements - Policy			
Firepumps	2	Adopt an on-condition maintenance strategy for the firepumps.	3.2.1.5
Firepump Motors	3	Adopt an on-condition maintenance strategy for the firepump motors.	3.2.2.4
Firepump Steam Turbines	4	Adopt an on-condition maintenance strategy for the firepump steam turbines.	3.2.3.6
FMS Valves	5	Continue an on-condition maintenance strategy for FMS valves.	3.2.4.1

APPENDIX A

SYSTEM BOUNDARIES FOR FIREMAIN, FLUSHING, AND WASHDOWN SYSTEM

This appendix defines the system boundaries of the firemain, flushing, and washdown system. Data for the firemain and flushing system are listed under SWABs 521-1 and 521-2. Data for the washdown system are listed under SWAB 523-1.

SWAB 521-1 includes authorized work for:

Firemain from the firepump discharge flange to firemain system throughout the ship, from firemain cutout valve to flushing pressure reducing station to flushing system throughout ship to end usage. SWAB 521-1 also includes piping and valves from inboard flange of sea valve to pump suction flange.

Associated Equipment:

Decontamination	Hose racks
Eductor supply	Operating gear
Fire plugs	Piping
Gauges	Strainers
Hangers	Traps
Hose	*Valves
Sound isolation joints	

Asterisks (*) identify equipments addressed in this analysis.

SWAB 521-2 includes authorized work for:

Turbine-driven firepumps, motor-driven firepumps, multiple-use pumps for firemain and flushing duties and all components between first flange of suction lines and first flange of discharge lines.

Associated Equipment:

Controllers (electrical)	Pressure gauges
*Couplings	Resilient mounts
*Governors (mechanical)(hydraulic)	Suction gauges
Label plates	Switches
Lube oil system	Thermometers
*Motors	*Turbines
Operating instructions	*Turbine steam valves

Asterisks (*) identify equipments addressed in this analysis.

SWAB 523-1 includes authorized work for:

Countermeasure washdown system from firemain root cutout valves, with all valves, piping, fittings and associated components, to the spray nozzles. Provides for repair and testing.

Associated Equipment:

Drains	Spray heads
Fittings	Strainers
Hangers	Switches
Nozzles	Valves
Operating	
Piping	

APPENDIX B

INSTALLATION CONFIGURATION OF FIREMAIN AND FLUSHING SYSTEM FOR LHA-1 AND LPH-2 CLASS SHIPS

The firemain and flushing system discussed in this report is composed principally of the components listed in Table B-1. The table provides detailed information on the individual component nomenclature, APL number, hull applicability, and number of components installed on each hull.

Table B-1. COMPONENTS OF THE FIREMAIN AND FLUSHING SYSTEM FOR LHA-1 AND LPH-2 CLASSES

Nomenclature (As Listed in APL)	APL/CID	Quantity by Hull											
		LHA-1	LHA-2	LHA-3	LHA-4	LHA-5	LPH-2	LPH-3	LPH-7	LPH-9	LPH-10	LPH-11	LPH-12
PUMP CTFGL, 1000GPM	016020537						2	2					
PUMP CTFGL, 1000GPM	016020842										8		
PUMP CTFGL, 1000GPM	016020956											8	
PUMP CTFGL, 1000GPM	016021444								2				
PUMP CTFGL, 2000GPM	016032346B	8	8	8	8	8							
PUMP CTFGL, 1000GPM	016110105						6						
PUMP CTFGL, 1000GPM	016110259									4			
PUMP CTFGL, 1000GPM	016110474												8
PUMP CTFGL, 1000GPM	016110502									4			
PUMP CTFGL, 1000GPM	016110600							6					
PUMP CTFGL, 1000GPM	016150937								6				
TURBINE STM	057950071						2	2	2	2			
TURBINE STM	057950104										2		
TURBINE STM	057950139											2	
TURBINE STM	057950140												2
TURBINE STM	057950185B	4	4	4	4	4							
MOTOR AC 300HP	174031358B	2	2	2	2	2							
MOTOR AC 300HP	174031359B	2	2	2	2	2							
MOTOR AC 125HP	174180119									6			
MOTOR AC 125HP	174750687						4	6					
MOTOR AC 125HP	174751787						1					5	6
MOTOR AC 125HP	174752576						1						
MOTOR AC 125HP	174754111											1	
MOTOR AC 125HP	174802584								6				
MOTOR AC 125HP	175503576										6		
FLEXIBLE COUPLING	780200061B	4	4	4	4	4							
FLEXIBLE COUPLING	780200063B	4	4	4	4	4							
FLEXIBLE COUPLING	782350006						8	8	2	8	8		
FLEXIBLE COUPLING	782540246												8
FLEXIBLE COUPLING	782350254											8	
FLEXIBLE COUPLING	782650011								6				

APPENDIX C

SUMMARY OF CASREP INFORMATION FOR FIREMAIN AND FLUSHING SYSTEM

The 68 CASREPs reported by the LHA-1 and LPH-2 Class ships were grouped into the five general categories of firepumps, ac motors, steam turbines, valves, and miscellaneous or unknown, and into the appropriate subgroup within each group on the basis of the initial cause reported for each CASREP. This information is presented in Table C-1. The table also shows the total number of CASREPs submitted for each different component for each initial cause, together with the total number of CASREP downtime man-hours due to supply and maintenance.

Table C-1. CASREP SUMMARY FOR FIREMAIN AND FLUSHING SYSTEM

Reason for CASREP	Number of CASREPs			CASREP Downtime Hours		
	LHA-1	LPH-2	Totals	Supply	Maintenance	Total
1. Fire Pumps						
• Internal repairs	1	13	14	3,154	16,859	20,013
• Mechanical seals or packing leaks	1	4	5	3,457	744	4,201
Subtotal	2	17	19	6,611	17,603	24,214
2. AC Motors						
• Motor shorted	1	16	17	5,076	14,404	19,480
• Bearings failed	0	8	8	0	8,208	8,208
• Shaft repair/ replacement	0	2	2	120	1,505	1,625
• Unknown	0	4	4	0	2,534	2,534
Subtotal	1	30	31	5,196	26,651	31,847
3. Steam Turbines						
• Exhaust/relief valve	0	3	3	320	3,164	3,484
• Unknown	3	2	5	9,430	879	10,309
Subtotal	3	5	8	9,750	4,043	13,793
4. Valve Repair/ Replacement	5	1	6	2,550	4,421	6,971
5. Miscellaneous	3	1	4	960	1,428	2,388
Totals	14	54	68	25,067	54,146	79,213

APPENDIX D

APPLICABLE MAINTENANCE INDEX PAGES

The following maintenance index pages (MIPs) were reviewed for this analysis:

A-604/P1-30	Firemain System
A-604/P2-87	Firemain System
E-5/54-91	Main Circulating Pump TD
E-17/326-89	Electric Driven Salt Water Pump
E-28/160-25	Electric Driven Fire Pump
E-28/212-21	Electric Driven Fire Pump
E-28/218-B8	Electric Driven Fire Pump
E-28/220-83	Electric Driven Fire Pump
E-28/240-87	Electric Driven Fire Pump
E-28/249-21	Electric Driven Fire Pump
E-28/254-83	Electric Driven Fire Pump
E-28/303-AO	Electric Driven Fire Pump
E-28/308-87	Electric Driven Fire Pump
E-28/336-C9	Electric Driven Fire Pump
E-37/55-90	Turbine Driven Fire Pump
E-37/62-A9	Turbine Driven Fire Pump
E-37/64-A9	Turbine Driven Fire Pump
E-37/72-90	Turbine Driven Fire Pump
EL-4/28-67	AC and DC Motors
A-616/2-83	Water Washdown System
A-616/1-91	Water Washdown System

APPENDIX E

CORROSION-CONTROL TECHNIQUES

Table E-1 presents the recommended work (SARP) statements for applying NAVSEA-approved corrosion-control techniques. Table E-2 presents specific guidance items for applying the corrosion-control techniques to common components within the firemain and flushing system (SWABs 521-1 and 521-2).

Table E-1. RECOMMENDED CORROSION-CONTROL SARP STATEMENTS

SWAB	Problem Area/ Components	Recommended SARP Statement	Alternate Corrosion-Control System(s)
5211	Firemain and Flushing	When firemain outlets are removed from the ship, apply WSA, low-temperature sealer. Use fasteners treated with ceramic coatings or use improved fasteners as applicable.	Apply polyamide epoxy paint. Apply strippable coatings to fasteners.
5211	Firemain and Flushing	When firefighting stations are replaced or represerved, apply polyamide epoxy paint. Use fasteners treated with ceramic coatings or use improved fasteners as applicable. Guidance item 2 applies to fasteners.	Apply topcoat. Apply strippable coatings to fasteners.
5211	Firemain and Flushing	When fog applicators are replaced or represerved, apply polyamide epoxy paint.	
5211	Firemain and Flushing	When firemain hangers are replaced, apply WSA with low-temperature sealer. Use fasteners treated with ceramic coatings or use improved fasteners as applicable. Guidance item 2 applies to hangers and fasteners.	Apply polyamide epoxy paint. Apply strippable coatings to fasteners.
5212	Pumps, Firemain, and Flushing	When firepumps are removed from the ship for overhaul or replacement, apply WSA with low-temperature sealer to foundations, bedplates, and casings. Apply polysulfide sealant to faying surfaces. Use fasteners treated with ceramic coatings or use improved fasteners as applicable. Guidance item 1 applies to machinery foundations, bedplates, and fasteners.	Apply polyamide epoxy paint. Apply strippable coatings to fasteners.

Table E-2. CORROSION-CONTROL GUIDANCE ITEMS		
Item Number	Equipment	Guidance
1	Machinery Foundations and Bedplates	When a new foundation or bedplate is installed or a bedplate is removed as part of machinery overhaul, or a foundation is located topside, abrasive-blast the foundation and mating structure surface to white metal (SSPC-SP5), and then apply 7-10 mils of WSA low-temperature sealer (MIL-P-23377) and two-coat polyamide epoxy (MIL-P-24441) system. For machinery foundations and bedplates located in machinery spaces and subjected to temperatures above 175°F, use WSA with high-temperature sealer (DOD-P-24555). Use fasteners treated with ceramic coatings or use improved fasteners.
2	Piping and Hangers	In areas exposed to the weather and in machinery spaces (where piping is replaced) abrasive-blast ferrous piping and pipe hangers/brackets to white metal (SSPC-SP5) and apply 7-10 mils of WSA, low- or high-temperature sealer (depending on operating temperature), and polyamide epoxy coating (MIL-P-24441). If piping is not replaced, apply three-coat polyamide epoxy system (MIL-P-24441). Treat fasteners with ceramic coating (MIL-C-81751) or use CRES fasteners.
3	Valves	Abrasive-blast valve exterior to white metal (SSPC-SP5) and apply 7-10 mils of WSA, low- or high-temperature sealer (depending on operating temperature of fluid or if steam valve), and polyamide epoxy coating (MIL-P-24441). Technical Manual NAVSEA S6435-AE-MMA-010/W, *Sprayed CTT, External Preservation of Steam Valves Using Wire Sprayed Aluminum Coatings*, provides detailed guidance. Upgrade/treat fasteners with ceramic coating (MIL-C-81751) or replace with CRES fasteners and apply polysulfide sealant (MIL-S-81733).

APPENDIX F

SOURCES OF INFORMATION

The specific sources of information used in this analysis are as follows:

1. Generation IV MDS narrative and part data for the LHA-1 and LPH-2 Class ships for the periods 1 May 1976 through 30 June 1981 and 1 January 1971 through 31 March 1981, respectively.

2. CASREPs for the same ships for the periods 1 January 1976 through 22 April 1981 and 1 January 1978 through 22 April 1981, respectively.

3. Maintenance index pages (MIPs) listed in Appendix D, and corresponding maintenance requirement cards (MRCs) for the firemain and flushing system.

4. NAVSHIP Technical Manuals:

   - 347-3242, *Warren Turbine- and Motor-Driven 500 GPM Firepumps*
   - 347-3913, *Duplex Water System*
   - 347-3914, *Water-Turbine-Driven Gasoline Pump*
   - 0947-031-9000, *Type 1 Manual, Centrifugal Pump for NTDS Liquid Cooling*
   - 347-3911.2, *Air Conditioning Sea Water Circulating Pump (T.D.)*
   - 347-3911, *Firepump, Motor- and Turbine-Driven*
   - 347-3239, *1000 GPM Firepump, Electric-Motor-Driven*
   - 347-1677, *Emergency Feed and Bilge Pumps*
   - 347-1706, *100 GPM and 250 GPM Firepumps (Worthington)*
   - 0947-0999-7010, *Type 1 Equipment Manual for 1000 GPM Firepump*
   - 0947-222-6010, *Type 1 Firepump Type 5 x 6 ASLD*
   - 347-4365, *Warren Motor- and Turbine-Driven 1000 GPM Firepumps*
   - 0947-079-4010, *Motor- and Turbine-Driven 1000 GPM Firepumps*

- 347-3440, *Aurora 1000 GPM Firepump, Motor-Driven*
- 347-4268, *Auxiliary Machinery Cooling Water Pump*
- 0947-220-6010, *Installation, Operation, Maintenance, and Repair Instructions with Parts List (Warren)*
- 0947-223-2010, *Installation, Operation, Maintenance, and Repair Instructions with Parts List (Warren)*
- 0947-195-4010, *Type 1 Equipment Manual for Firepumps*
- 0947-174-0010, *Pump, Fire, Jet Blast Deflector Cooling Service Type on Model 5 mm x 5*
- 0947-132-7010, *Type 1 Combined Manual for 1000 GPM Firepump Motor- and Turbine-Driven*
- 0347-318-4003, *Warren Turbine- and Motor-Driven 500 GPM Firepumps*
- 0347-334-1000, *Aurora Electric Motor and Steam-Turbine-Driven Firepumps*

5. Ship Alteration and Repair Packages (SARPs):

   - LPH-2 dated 6/8/82
   - LPH-3 dated 3/11/82
   - LPH-7 dated 10/31/80
   - LPH-9 dated 8/18/80
   - LPH-10 dated 1/9/81
   - LPH-11 dated 10/23/81
   - LPH-12 dated 5/15/81
   - LHA-1 dated FY 78 RAV
   - LHA-2 dated 6/13/83 (COH)
   - LHA-1 dated FY 81 (COH)
   - LHA-3 dated 1/15/82 SRA
   - LHA-2 dated 7/3/81 SRA

6. Ship Alteration Information Manuals for LHA-1 and LPH-2 Class Ships.

7. COMNAVSURFLANT and COMNAVSURFPAC Type Commander's Coordinated Shipboard Allowance Lists (COSALs), dated July 1981 and June 1981, respectively.

8. COMNAVSURFLANTINST 9000.1, *NAVSURFLANT Maintenance Manual*, 12 June 1975, through change 5, dated 27 February 1978.

9. COMNAVSURFPACINST 4700.1, *COMNAVSURFPAC Ship and Craft Material Maintenance Manual*, Volume I, 6 June 1975.

10. OPNAVINST 4790.4, *Material Maintenance Management (3-M) Manual*, Volumes I, II, and III; June 1973.

11. *FF-1052 Class Firemain System Review of Experience*, SMA 203-521, November 1977, ARINC Research Publication 1652-30-3-1678.

12. *DDG-37 Class Firemain and Auxiliary Machinery Cooling Water Systems Review of Experience*, SMA 37-201-521, February 1978, ARINC Research Publication 1652-03-10-1715.

13. *CG-16 and CG-26 Class Auxiliary Systems Review of Experience*, SMA 1626-500, September 1979, ARINC Research Publication 1671-04-3-2051.

14. System Engineering Analysis of Firemain of Flushing System Installed on AD-14, AD-37, AFS-1, AO-177, AOE-1, AOR-1, AR-5, AS-11, AS-19, AS-31, AS-33, and AS-36 Class Ships.

15. Common Class Configuration Lists (CCCL) for LHA-1 and LPH-2.

16. Ship Work Authorization Boundaries (SWABs) for Surface Ships, March 1981.

17. Class Maintenance Plans (CMPs) for FF-1052, DDG-37, CG-16, CG-26, and LHA-1 Class ships.

18. Repair Profile for LPH-2 Class ships.

19. Results of ARINC Research Corporation visits to LPH-7 (USS GUADALCANAL) and LPH-12 (USS INCHON) on 20-21 April 1982.

20. Results of ARINC Research Corporation visit to LHA-2 (USS SAIPAN) on 4 June 1982.